FINAL REPORT

COOPERATIVE EVALUATION SURVEY OF CHERMES DAMAGE MOUNT ST. HELENS, WASHINGTON, 1957

by

Robert B. Pope

U. S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
Pacific Northwest Forest and Range Experiment Station

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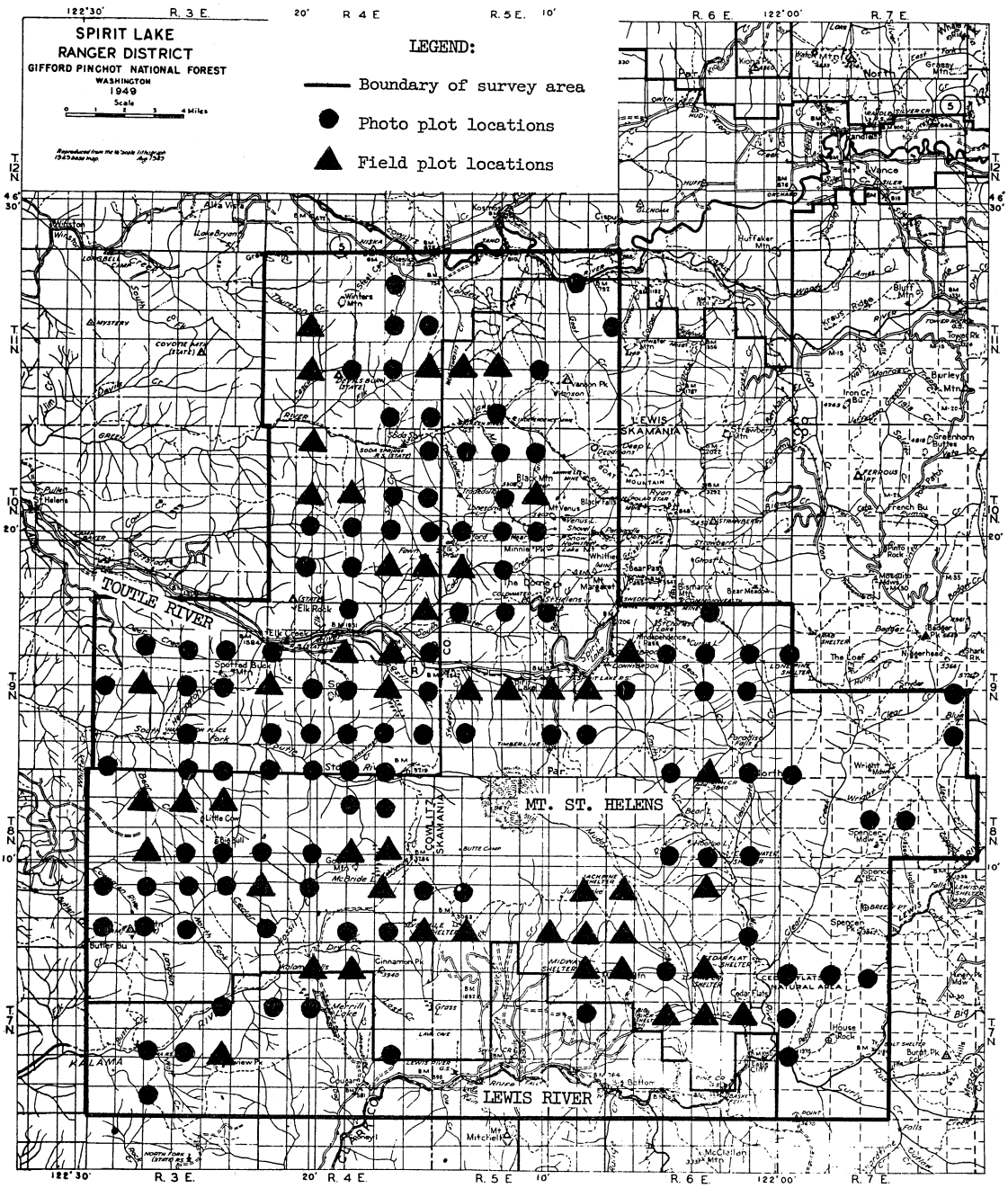
TABLE OF CONTENTS

APPENDIX



Map of Survey Area, Showing Survey Boundary
and Location of Photo and Field Plots

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Abstract

Damage caused by the balsam woolly aphid, at present the most destructive forest insect pest in the Pacific Northwest, is severest in the vicinity of Mount St. Helens, Washington. The major landowners in the area have cooperated in a survey to evaluate this damage and establish a base from which to measure future loss trends.

The survey was designed to obtain a reliable estimate for the total amount of dead and heavily damaged true firs with a minimum amount of field work. Provision was also made for breaking down this total by species and ownership, recognizing that the reliability of these estimates decreases as the breakdowns get finer. The damage estimates were obtained by combining interpretation of large-scale aerial color photographs with field checks using standard statistical procedures. Use of the photographs enabled the field work to be reduced to about 25 percent of that required for a straight field survey of comparable accuracy. In addition, the photographs form a detailed permanent record which cannot be obtained in any other way.

The results of this survey show that within the boundary of the area shown on the accompanying map, containing about 413,000 gross acres, there is an estimated 6 billion board feet of true fir, gross volume. A little more than half of this volume has been damaged by the balsam woolly aphid, the damage being about equally divided between trees that are dead or heavily damaged, and those that are lightly to moderately damaged. Over 80 percent of the dead and heavily damaged volume is on the two major ownerships, Weyerhaeuser Timber Company and the Gifford Pinchot National Forest.

Introduction

The most serious forest insect infestation in the Pacific Northwest at present is that of the balsam woolly aphid. Since its detection in 1954, it has spread over nearly 600,000 acres. It has killed and seriously damaged large numbers of the true firs, mainly Pacific silver fir and subalpine fir. The most seriously affected area is in the vicinity of Mount St. Helens, Washington, where large amounts of merchantable timber are being killed.

Each year since 1954 the areas of infestation have been mapped by aerial reconnaissance as part of the Regional Forest Insect Survey conducted by the Pacific Northwest Forest and Range Experiment Station and its cooperators. These maps show the location of the current infestation by four intensity classes, but do not provide any estimate of the volume of dead or damaged timber. Such an estimate is needed in order to evaluate the magnitude of the damage and its impact on the forest industries of the area. The volume estimate should be kept current in order that salvage operations can be planned more intelligently.

Because of this need, a survey was conducted in the area around Mount St. Helens as shown on the accompanying map. It was a cooperative project participated in by the U. S. Forest Service, Washington State Department of Natural Resources, Weyerhaeuser Timber Company, Harbor Plywood Corporation, and Northern Pacific Railroad. The major objectives were to provide an estimate of the total volume of dead and damaged true firs and to furnish a base so that future trends could be evaluated. At the same time it provided an opportunity to test, on an operational basis, an aerial photo survey technique which has appeared promising in limited exploratory tests. The Regional Office, Region Six, U. S. Forest Service, was responsible for administrative control. Design of the survey, aerial photography, photo interpretation, analysis and reporting were conducted by the Pacific Northwest Forest and Range Experiment Station. Field work was done by the major landowners in the area.

Objectives

1. To provide an estimate of the total volume of true firs, by ownership and species, in each of the following individual tree damage classes:

    a. Dead
    b. Heavily damaged
    c. Lightly to moderately damaged
    d. Undamaged

2. To provide an estimate of the average species composition for those stands which contain true firs.

3. To provide a rough estimate of what the various mapped infestation classes mean in terms of proportion of the true fir volumes in the above individual tree damage classes.

4. To establish a base for determining the trend of damage annually or periodically.

5. To test, on an operational scale, an aerial survey technique which has shown promising results in initial limited experiments.

6. To gather data for studies of the types and locations of stands preferred by the insect.

This report deals with results obtained in satisfying the first three of the above objectives. Results concerning the remaining objectives and a detailed discussion of techniques will be given in other reports.

Survey Methods

The choice of a suitable survey method was influenced by two primary considerations. (1) Field work had to be kept to a minimum. There was only a short time between late August, when the damage shows up best, and early October, when bad weather might stop field work at the higher elevations. There was also a scarcity of trained field crews available for this project. (2) Emphasis was to be placed on the major objectives of estimating the total amount of dead and heavily-damaged timber, and establishing a base for measuring future trend. Breakdowns of the totals, and information on inventory volumes of all species, was considered secondary.

The use of field work alone was ruled out because there was neither time nor manpower available in sufficient quantities to meet the objectives. Visual aerial observation was also ruled out, because it is not suited to the gathering of permanent in-place information for the measurement of trends. The method chosen combines aerial photo interpretation, using special large-scale color photos, and field checking to provide the necessary adjustments. It is called double sampling, or regression sampling, and provides a maximum amount of information for the effort expended. This survey has been accomplished with about 25 percent of the field work that would have been required to meet the major objectives by field work alone.

Preliminary proposals for survey methods were discussed by representatives of all cooperators at two meetings. Revisions were made and a final plan adopted in July 1957. The plan was reproduced and distributed to all cooperators prior to the start of the survey.

The boundary of the survey area was laid out to encompass the bulk of the infestation in the vicinity of Mount St. Helens as determined by the 1956 Forest Insect Survey. Within this boundary all available information was gathered on the location of merchantable sawtimber stands containing any of the true firs. 160 plots, systematically-spaced within these stands, were photographed on color film at a scale of about 1:4,000. Photography was done in August when the damage shows up best. Each photo plot was interpreted and an estimate was made of the volume of true firs in the various damage classes on a 1/2-acre plot. 49 of these plots were visited in the field and the volumes of all trees were tallied. A majority of the field work was concentrated in the relatively accessible areas to further reduce the field work load.

Final estimates of the true fir volumes in the various damage classes were made by adjusting the large photo-plot sample, using data obtained from the smaller sample of plots which had been field checked. The adjustments were based on linear regressions.

Details of the survey method are contained in the appendix.

Results

The tables that follow summarize the data on the amounts of damage by ownership and species, and the average species composition of the stands that were sampled -- the first two objectives of the survey.

Data on the amounts of damage by mapped infestation classes are not included here, because a change in thinking has occurred and a new approach is being investigated. The original plan called for evaluating the mapped infestation classes in terms of damage proportions obtained from the plot survey. However, the map shows current infestation as of August, 1957, and the plots show cumulative damage since the beginning of the infestation in 1954. The two types of damage are not necessarily related. A more logical approach would be to try and construct a cumulative damage map by combining all the current damage maps. This approach is being explored and the results will be reported later.

The results of this survey as a test of a survey technique will be covered in a special report, probably in a technical journal. However, a summary of the preliminary conclusions is included in this report, since it should be of some aid in interpreting the results of this report.

Interpretation of Results

This survey has employed some techniques and shortcuts which differ from most conventional survey methods. This makes it important that the reader be aware of certain features in the survey design in order to properly interpret the results. Maximum value from this survey can best be obtained by considering the data in the light of the survey purpose, the methods used, and the effort expended.

Survey Purpose

In examining the results of this survey it is important to keep in mind the major objectives. Attempts to use the data for purposes other than those intended may result in misleading interpretations.

The major purpose of the survey was to provide a reliable estimate of the total amount of dead and damaged true fir, and establish a base from which to measure future loss trends. The survey was designed, and the amount of effort determined, mainly by these objectives. At the same time it was desired to obtain estimates of ownership and species breakdowns for these totals, and an approximation of the average species composition for the stands sampled. It was not the purpose of this survey to provide the cooperators with inventories of their forest land, nor to obtain detailed in-place estimates of dead and damaged timber.

Survey Methodology

A knowledge of the methods used on this survey will help the reader to judge how much reliance can be placed on various portions of the resulting data. Wherever statistically possible, reliability of the data has been stated in the form of sampling errors. However, certain data presented here were arrived at by methods of approximation which prevent the determination of sampling errors. For these figures an estimate of reliability can be made only by understanding how they were obtained.

A brief summary of the methodology has already been given, and further details are contained in the appendix. A few points need to be emphasized here in connection with the interpretation of results.

Most of the data for this survey come from two sources -- photo interpretation and field plots. Both types of information have been combined by sound statistical procedures to produce estimates of the dead and damaged timber for the three major ownership classes. These are the figures, shown in Tables 1 and 3 with their sampling errors, that are the strongest part of this survey. The area figures in Table 2 are also relatively strong because they were obtained from an intensive dot count of the map showing types to be sampled.

The estimates in Table 1 for the individual ownerships that were grouped together are not as strong because they were obtained by using a pooled average volume for all owners in the group. Nor are the species and ownership breakdowns shown in Tables 4 and 5 as reliable as the total volumes in Table 1. They were necessarily obtained from field plots only, without the strengthening benefit of the additional photo plots. This decrease in reliability from totals to finer and finer breakdowns is characteristic of all surveys of less than 100% intensity, whether they be performed with photos, in the field, or by a combination of both methods.

The data in Tables 1 and 3 come from one source of information (combined photo and field plots), while Tables 4 and 5 are based on a different source (field plots only). Each type of information is subject to sampling errors, and some may be plus while others are minus. Because of this it is risky to attempt combining data from the two groups of tables to produce a type of information not provided by this survey. It is believed that the tables included in this report present all the information reasonably obtainable from this survey, and readers are cautioned against attempting to spread the data any thinner.

When interpreting any of the tables in this report, and comparing results with those from other surveys or previous estimates, keep in mind that the volumes shown here are gross, and include cull trees and cull portions of merchantable trees.

Effort Expended

The results of this survey should be weighted against the effort expended, for with any survey system the accuracy and variety of information can be increased by spending more time and money.

The total cost of this survey was about $10,000. Approximately 17 man-weeks of field work was involved -- contributions from individual cooperators varied from about 1 man-week to about 8 man-weeks. An analysis of the field data indicates that to have accomplished the primary survey objective with the same degree of reliability, using field work alone, would have required about 65 man-weeks field work and cost about $15,000.

Sufficient effort was expended on this survey to obtain a reasonable estimate of the total volume of dead and damaged true fir. As with any survey, the breakdown of the total into portions, such as individual ownerships, is less reliable than the total, and the smaller the portion the greater the sampling error. No special effort was made to obtain sampling errors on the smaller ownerships equal to those on the larger, for this involves considerable expense. It is estimated that this could have been done by aerial photography at an additional cost of about $5,000, or by additional field work at a cost of about $35,000.

Table No. 1

Total Gross Volume of True Firs by Ownership and Tree Damage Class

This table, and the illustrating graph (shown on page 8) summarize the data from the major objective of the survey.

The total gross volume of all true firs in the survey area is estimated to be 6 billion board feet. Nearly half of this volume is in trees which are less than 5-percent damaged. The remainder is almost equally divided between trees which are lightly to moderately damaged and those which are heavily damaged or dead. The two major owners, Weyerhaeuser Timber Co., and the Gifford Pinchot National Forest, have about 84% of the total true fir volume and 83% of the dead and heavily-damaged class.

It is recognized that the total volumes for true firs of all damage classes may not agree with the existing estimates of some owners. Before making comparisons between data from this survey and existing cruise data, it is necessary to adjust for the difference in standards. The volumes shown here are gross volumes, and there may be other differences, such as diameter limits. It is presumed that some owners have figures on their total true fir volume which are more reliable than those provided by this survey. In this case, the best procedure would be to use the proportions of the various damage classes, obtained from Table No. 1, and apply them to their own estimates of total true fir volume.

Cooperative Evaluation Survey of Chermes Damage -- Mount St. Helens, Wn., 1957.

Table No. 1--Total gross volume[1] of true firs by ownership and tree damage class.

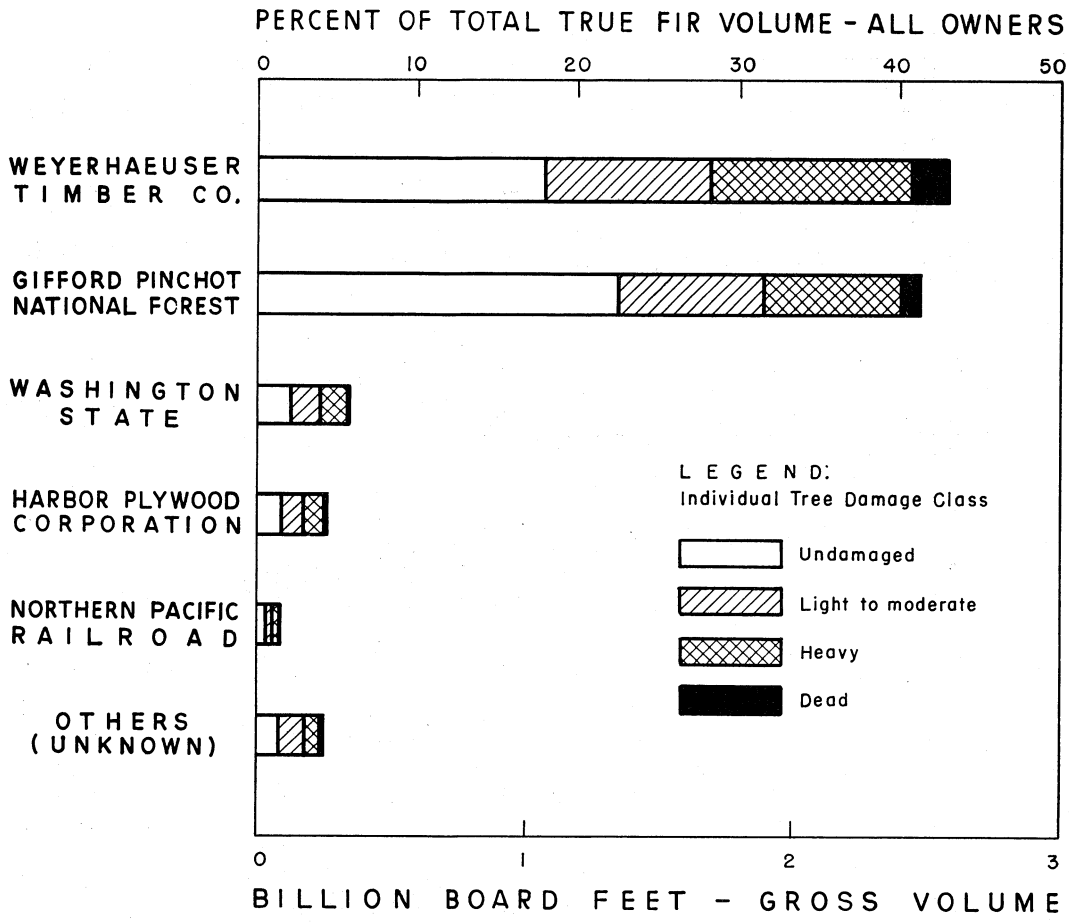
Ownership	Individual Tree Damage Class[2]							
	Dead	Heavy	Subtotal Dead plus Heavy		Light to moderate[3]	Undamaged[3]	Total-All True Fir	
	MM bd.ft.	MM bd.ft.	MM bd.ft.	Stand.error[4]	MM bd.ft.	MM bd.ft.	MM bd.ft.	Stand.error[4]
Washington State	14	91	105		114	118	337	
Harbor Plywood Corp.	12	72	84		90	94	268	
Northern Pacific R.R.	3	23	26		28	30	84	
Miscellaneous (unknown)	11	67	78		84	88	250	
Subtotal, Minor Owners	40	253	293	±20%	316	330	939	±24%
Gifford Pinchot N.F.	64	516	580	±20%	549	1,343	2,472	±15%
Weyerhaeuser Timber Co.	148	744	892	±17%	612	1,088	2,592	±16%
Total	252	1,513	1,765	±13%	1,477	2,761	6,003	±13%

1/ Gross volume of all live trees 11.0" d.b.h. and larger to merchantable height approximately 40% of d.b.h., in Scribner log scale. Includes cull portions of merchantable trees and cull trees.

2/ Individual tree damage classes defined as follows: Dead--trees that have died in the last four years. Heavy--50% or more of crown dead, gouted or lacking new foliage. Light to moderate--5% to 50% ditto. Undamaged--less than 5% ditto.

3/ Breakdown between and within these two classes based on field plots only and, therefore, not as reliable as the other damage classes which are based on both photo and field data.

4/ The standard error expresses the reliability of the estimate. It means that the chances are two out of three that the estimated volume is within the listed percent of the true volume. Standard errors could not be calculated for the minor ownerships, because a pooled per-acre volume was used for all of them.



Graph No. 1 -- Total gross volume of true firs by ownership and tree damage class

Table No. 2

Area Sampled by Ownership

This table shows the area of the timber stands that were sampled in each ownership. These areas were used, in conjunction with the per-acre volumes shown in Table No. 3, to obtain the total volumes in Table No. 1.

The gross area within the boundary of the survey area contains about 413,000 acres. Slightly more than half of this area was eliminated from the possibility of being sampled. According to the best available information, it consists of nonforest, nonstocked, noncommercial, subalpine, or other types which do not contain commercial volumes of true firs.

The remainder, 202,300 acres, is composed of sawtimber stands containing commercial volumes of true firs. This is the area sampled by the survey. The table reveals the wide range in size of ownership among the cooperators. The largest cooperator owns 46% of the area sampled, while the smallest owns only 2%. The two largest owners together account for 80% of the sample area.

Cooperative Evaluation Survey of Chermes Damage
Mount St. Helens, Wn., 1957

Table No. 2--Area sampled by ownership[1/]

Ownership	Acres	Standard error	Proportion of area sampled (Percent)
Weyerhaeuser Timber Co.	93,780	± 3%	46
Gifford Pinchot N. F.	68,590	± 4%	34
Washington State	14,330	± 9%	7
Harbor Plywood Corp.	11,380	±10%	6
Northern Pacific R. R.	3,590	±18%	2
Others (unknown)	10,630	±11%	5
Subtotal -- area sampled[2/]	202,300	± 2%	100
Area not sampled[3/]	210,700	--	--
Total -- gross area, survey unit	413,000	--	--

1/ Determined from a dot count of a map showing the survey boundary and all areas within it to be sampled.

2/ Includes all areas which, according to the best available information, contain commercial volumes of any of the true firs.

3/ All other areas. Includes nonforest, noncommercial, subalpine, non-stocked, stands less than sawtimber in size, and those sawtimber stands which contain less than 20% true firs.

Table No. 3

Average Per-acre Gross Volumes of True Firs by Ownership and Tree Damage Class

This table shows the average per-acre gross volumes that were applied to the areas of Table No. 2 to produce the total volumes shown in Table No. 1.

The average gross volume of all true firs, for the stands that were sampled, is about 30,000 board feet per acre. The Gifford Pinchot National Forest has the highest per-acre gross volume for all classes of true fir, Weyerhaeuser Timber Co., is about average, and the remaining owners, as a group, are below average. However, the per-acre volume of dead and heavily-damaged timber is heaviest on Weyerhaeuser ownership, about average for the Gifford Pinchot National Forest, and less than average for the remaining ownerships as a group.

Cooperative Evaluation Survey of Chermes Damage -- Mount St. Helens, Wn., 1957

Table No. 3--Average per-acre gross volumes[1] of true firs by ownership and tree damage class.

Ownership	Individual Tree Damage Class[2]							
	Dead	Heavy	Subtotal Dead plus heavy		Light to moderate[3]	Undamaged[3]	Total-All True Fir	
	bd.ft.	bd.ft.	bd.ft.	Stand.error[4]	bd.ft.	bd.ft.	bd.ft.	Stand.error[4]
Weyerhaeuser Timber Co.	1,579	7,934	9,513	±16%	6,523	11,598	27,634	±16%
Gifford Pinchot N. S.	932	7,528	8,460	±19%	7,999	19,586	36,045	±14%
All others	989	6,335	7,324	±20%	7,932	8,257	23,513	±23%
Average, All Owners	1,234	7,481	8,724	±13%	7,302	13,646	29,672	±13%

1/ Gross volume of all live trees 11.0" d.b.h. and larger to merchantable height approximately 40% of d.b.h., in Scribner log scale. Includes cull portions of merchantable trees and cull trees.

2/ Individual tree damage classes defined as follows: Dead--trees that have died in the last four years. Heavy--50% or more of crown dead, gouted or lacking new foliage. Light to moderate--5% to 50% ditto. Undamaged--less than 5% ditto.

3/ Breakdown between and within these two classes based on field plots only and, therefore, not as reliable as the other damage classes which are based on both photo and field data.

4/ The standard error expresses the reliability of the estimate. It means that the chances are two out of three that the estimated volume is within the listed percent of the true volume. Standard errors could not be calculated for the minor ownerships, because a pooled per-acre volume was used for all of them.

Table No. 4

Approximate Species Breakdown of True Fir Volumes--
Percentage by Gross Volume

While the species breakdowns of total true fir volumes by damage class and ownership class are only approximations, they confirm empirical observations that have been made. By far the bulk of the commercial forest damage done by the balsam woolly aphid has been to silver fir. All of the dead and heavily-damaged classes, and 90% of the lightly to moderately-damaged class, is silver fir, while this species accounts for only a little over half of the undamaged class.

Cooperative Evaluation Survey of Chermes Damage -- Mount St. Helens, Wn., 1957.

Table No. 4--Approximate[1/] species breakdown of true fir volumes -- percentage by gross volume.

Tree Damage Class	Species	Ownership			
		W.T.Co.	G.P.N.F.	Others	Average
		(Percent)	(Percent)	(Percent)	(Percent)
Dead	Silver fir	100	100	100	100
Heavy	Silver fir[2/]	100	100	100	100
Light to moderate	Silver fir	90	85	95	90
	Noble fir	10	15	5	10
Undamaged	Silver fir	50	50	75	55
	Noble fir	45	50	25	45
	White fir	5	--	--	*

1/ Species breakdown is only approximate, and is estimated to the nearest 5 percent. Estimates are based on data from field plots only, which necessitated the pooling of some data for all ownerships.

2/ One noble fir tree was tallied in the field in the heavily-damaged class. However, it was arbitrarily shifted to the moderate class because entomologists have not found any case where heavy damage to noble fir has been caused by the balsam woolly aphid.

* Less than 2-1/2%.

Table No. 5

Approximate Species Composition of Stands Sampled -- Percentage by Gross Volume.

The data for this table indicate that, for the stands sampled, a little less than half of the gross volume is in the true firs. Two-thirds of this true-fir volume is Pacific silver fir, most of the remainder being noble fir, with only a trace of white fir. The rest of the gross volume in these stands is about equally divided between Douglas-fir and western hemlock, with traces of minor species, the most prominent of which is western red cedar.

The species composition for Weyerhaeuser ownership, and for the minor owners as a group, is approximately the same as the average for all owners. However, the composition on the Gifford Pinchot National Forest runs heavier to Pacific silver fir and noble fir, and consequently less of the other species, particularly Douglas-fir.

Table No. 5--Approximate[1] species composition of stands sampled[2] -- percentage by gross volume.

Species	Ownership Class			
	W.T.Co.	G.P.N.F.	Others	Average All owners
	(Percent)	(Percent)	(Percent)	(Percent)
Pacific silver fir	25	40	35	30
Noble fir	15	25	10	15
White fir	*	--	--	*
Douglas-fir	30	15	25	25
Western hemlock	20	20	25	20
Western red cedar	5	*	*	5
Western white pine	*	--	*	*
Alaska-cedar	*	*	*	*
Red alder	*	--	*	*

1/ Species composition is only approximate, and is estimated to the nearest 5 percent. Estimates are based on field plots only, which necessitated the pooling of some data for all ownerships.

2/ Species composition estimates apply only to those stands sampled by field plots. These are the stands that actually contain true fir -- an unknown portion of the 202,300 acres sampled by the photo plots.

* Less than 2-1/2 percent.

Preliminary Conclusions on the Efficiency of the Aerial Photographic Method

The results of this survey as a test of an aerial photographic technique will be given in a special report after some additional analyses and cost estimates have been made. However, some preliminary data are available and may be of interest to the cooperators.

The major purpose of the technique used in this survey was to reduce the amount of field work and consequently reduce the cost and the field time required for the survey. The best measure of the efficiency of the method is a comparison of its cost with the cost of a straight field survey which would fulfill the major objective with the same degree of accuracy.

The regression-sampling technique used in this survey provided an estimate of the total volume of dead and heavily-damaged true fir with a sampling error of 13.3%. Standard accepted statistical procedures were used to obtain the estimate of volume and of the sampling error. Preliminary cost estimates have also been made, and are as realistic as possible. It was assumed that the aerial photography would have to be purchased from an aerial contractor and the cost figures used are 30-percent higher than the actual costs incurred by the Experiment Station. It was assumed that the aerial survey method would require extra time and expense for planning, analysis, and reporting. The saving occurs in the reduction of the number of field plots and also of the average cost per plot, through concentration in the accessible areas.

The number of field plots required for a straight field survey of comparable accuracy, and the cost of this survey, were estimated from the same data and on the same basis as the double-sampling survey. These data indicate that a random or systematic field survey would require about 175 field plots and the total cost of such a survey would be nearly $15,000. The double-sampling survey, involving 160 photo plots and 50 field plots would cost about $10,000, a saving of about one-third. The regression-sampling survey required 17 man-weeks of field work, while a field survey would have required about 65 man-weeks. This represents an important saving of field time at a period when suitable weather is becoming questionable.

The evidence from this survey clearly indicates that a combination of aerial photo interpretation and field checking is more efficient than straight field work for estimating the volumes of dead and damaged true firs. However, certain types of data, such as species breakdowns, must come from field plots only, and these are naturally stronger under a straight field survey system where more field plots are taken. If this type of data is important, and worth the extra cost, then a straight field survey may be the only answer.

Conclusions

When the results of this survey are compared with the objectives it must be concluded that for the most part, the survey has been a success.

Objective No. 1, an estimate of the total volume of true firs in the various damage classes, has been accomplished at considerably less cost than a straight field survey of comparable accuracy. The breakdown of these totals by ownership is more reliable than that which could have been obtained by an equal expenditure for a field survey. However, the latter would have provided a better estimate of species breakdown.

Objective No. 2, an estimate of the average species composition for stands sampled, has been provided. A straight field survey would have furnished better species breakdowns, but this was considered a minor objective, not worth the extra expense necessary to gain additional accuracy.

Objective No. 3, an evaluation of the mapped damage classes, has not been met, and it is possible that it will not be. This has nothing to do with the survey system used, but is due to a change in thinking since the objective was set up. The problem is one of trying to assemble information on cumulative damage by areas from a number of annual current damage maps.

Objective No. 4, establishment of a base from which to measure future damage trends, has been accomplished. It could have been accomplished as well by a straight field survey.

Objective No. 5, to test an aerial photographic survey technique, has been met. Sufficient data have been collected to provide a comparison of the accuracies and costs between a straight field survey and one based on a combination of photo interpretation and field checking.

Objective No. 6, to gather supplementary data on the types and locations of stands preferred by the insect, has also been accomplished. Certain information, such as presence or absence of bole infestations or swampy conditions, would have been provided in greater quantities by a straight field survey. Other information, such as the association of damage with cutting areas, is better provided by the aerial photographs.

On the whole, then, the objectives have been largely met, and at a reasonable cost. The use of large-scale aerial color photographs appears to have merit for the purpose of estimating the amount of true fir killed or damaged by the balsam woolly aphid. On the basis of the results from this test, the method can be recommended in the future for surveys to evaluate the damage caused by balsam woolly aphid outbreaks.

APPENDIX

Description of Survey Methods Used

A general description of the approach and methods used on this survey is contained in the body of this report. Following is a detailed description of procedures employed.

Boundary of Survey Area.

The boundary of the area to be surveyed was arbitrarily drawn along land lines to include the bulk of the concentrated damage in the vicinity of Mount St. Helens, as shown on the 1956 Regional Forest Insect Survey map. This boundary encompasses about 413,000 acres, gross area, and is shown on the map at the front of this report.

Determining the Areas to be Sampled.

It was known that a large portion of the gross survey area consisted of types which could not possibly be damaged by the balsam woolly aphid — that is, nonforest, noncommercial, nonstocked, or forest types containing insignificant amounts of the true firs. Since the major objective of the survey was to estimate the amount of dead and damaged true fir, considerable effort would be wasted by putting photo or field plots in those areas which did not contain commercial volumes of true fir.

In order to reduce this wasted effort as much as possible, a map was made showing, by ownership, those types which were believed to contain true firs. Information was compiled from all available sources. Type maps supplied by the cooperators, Forest Survey Type maps, the 1956 Regional Forest Insect Survey map, and examination of available aerial photos were all used in constructing this map. The final map, at a scale of 1" = 1 mile, showed by ownership those forest types which, according to the best available information, were commercial sawtimber types containing 20% or more net volume in any of the true firs. A dot count of this map showed that a little less than half of the gross survey area, or about 202,300 acres, were mapped in as types to be sampled. The remainder, 210,700 acres, were excluded from any possibility of being sampled.

It was recognized that this map showing the types to be sampled was not perfect. The kind of information required simply was not available for all areas within the survey boundary. An effort was made to be conservative and include those questionable areas which might or might not contain true firs. This resulted in a certain amount of waste effort -- that is, aerial photographs were taken of some plots which turned out to have no true fir -- but this was believed preferable to the alternative of not sampling these questionable areas, with the possibility of missing some dead or damaged true fir. In spite of these precautions, there is undoubtedly some dead or damaged true fir which was excluded from the types to be sampled because of erroneous forest type information. It is believed, however, that this amount is so small as to be insignificant.

Establishing the Photo Plots.

It was estimated that about 160 photo plots and 50 field plots, 1/2-acre in size, would be needed to produce an estimate of the total volume in dead and damaged true firs with a standard error of 10%. These figures had to be based on rough estimates, since very little data was available on the nature of volume losses caused by the balsam woolly aphid.

A mechanical grid was designed so that when it was laid on the map of types to be sampled, 160 points fell in these types. The spacing required to accomplish this turned out to be about 1.4 miles, both N-S and E-W. Each of these 160 points that fell in types to be sampled was marked on the map and numbered as a photo plot.

Photographing the Photo Plots.

Each photo plot was marked on 1" = 1 mile base maps and each was also marked on available aerial photographs. These prints varied in scale from 1:12,000 to 1:45,000. The photo crew was furnished both maps and photos to guide them to the location of each photo plot. At each one of these photo plot locations an overlapping pair of photographs was taken. Color film was used at a scale of about 1:4,000 with a 12" lens and 80%-90% overlap to reduce the excessive parallax at this large scale.

Selecting the Field Plots.

It had been determined that about 50 of the 160 photo plots should be field checked in order to obtain data for adjusting the photo plot sample. In selecting the particular plots to be checked several problems arose, and certain shortcuts were taken to minimize them. The problems and shortcuts are described below.

Presence or absence of true fir on the plot. Despite the fact that the bulk of the types not containing true fir had been eliminated from the sample, it was still possible that some of the photo plots would not have any true firs. This is partly due to errors in the type information and partly because of the broad acreage minimums on some of the type maps. Obviously it would be a waste of time and effort to send a field crew out to measure chermes damage on a plot that doesn't have any true fir. In order to minimize this risk, each plot was given a preliminary examination on the photos. If no true fir trees could be detected on the plot or in the near vicinity, then that plot was automatically considered a zero-volume plot and was not given a chance to be field checked. Past experience had indicated that true firs could be easily identified on large-scale color photos, and a field check of some of the plots thus rejected indicated that this assumption was justified.

Plot accessibility. Some of the country within the survey unit is fairly rugged and inaccessible. Field plots in these areas would be quite expensive. It was felt desirable to minimize this type of field work if it could be done without incurring the likelihood of getting a serious bias. Since the field plots were required to obtain a representative sample of the photo-field relationship, and not of the average amount of damage, it seemed reasonable that some restriction by accessibility class would not create much risk of bias.

Examination of the photo plot locations revealed that about half of them were within one mile of a road and the other half were further. It was arbitrarily decided to select 80% of the field plots (40 plots) from those photo plots falling within one mile of a road, and the remaining field plots (10) from those photo plots further than one mile. It was felt that this would make a substantial reduction in the time and cost of the field work without incurring much risk of bias.

Ease of location. The adjustment of the large photo plot sample is based on data obtained by field checking a portion of these plots. It is essential that the field check plots be located in exactly the same position as the corresponding photo plots. If they are not, then there is unlikely to be any correlation between the photo estimates and the field checks, and no benefit will be gained from the photo plots.

An effort was made to minimize the chance for field plot mislocation errors. A few of the photo plots fell in large unbroken stands having no visible stand characteristics or topographic features to use as reference points for plot location. These plots were eliminated as possible field samples. Plots to be field checked were systematically selected from the remaining photo plots. The actual location of each plot was midway between the two centers of the overlapping pair of photos, providing there was some visible stand characteristic or topographic feature nearby to use for a plot reference. If necessary, the plot starting point was moved so as to tie into the nearest reference feature visible on the photo.

Field Work.

Field work was accomplished by field crews, generally two men each, furnished by the cooperators. Photographic prints were made from the color transparencies and the plot locations were marked on them. These were furnished to the field crews, along with maps and normal-scale photos, to be used as guides in locating the plots. Crews were required to find their way to the plots and identify the location by means of photo interpretation.

The plots were 1/2 acre in area, one chain by five chains. The plot center line was chained out and marked on the ground so that check cruises could be made. On each plot a complete tally was made of all sound live sawtimber trees and any dead true firs that had died in the last four years. Each tree was tallied by species, 2" d.b.h. class, and merchantable height. In addition, each true fir was given a damage classification, based on appearance of the crown, as dead, heavily damaged, lightly or moderately damaged, or undamaged. Fifteen of the field plots were considered permanent, and on these each live true fir was tagged.

Field Plot Checking. Some of the field plots were checked by an experienced photo interpreter and a forest entomologist. Eighteen plots were checked for accuracy of location, 13 of these for trees tallied, and 8 of these were further checked for true fir damage classification.

Plot locations were found to be generally correct. Of the 36 starting and ending points, 3 were found to be in error by 1/2 to 1 chain. The damage classifications averaged out remarkably close to the check classifications made by the forest entomologist. Differences occurred on individual trees, but these balanced out so that the proportion of trees in each damage class was the same on the original plots as on the check plots.

The biggest discrepancy uncovered in the check cruising was that a considerable number of trees was missed in the original tally. On the 13 plots check-cruised a total of 53 trees was missed. Total gross volumes on these plots averaged 10.4% below the check cruise volumes and were as much as 40% low on individual plots, largely due to missed trees. The evidence from the check cruise indicates then that the field volume data is conservative and, therefore, that the final adjusted gross volume estimates are probably slightly low.

Photo Interpretation.

The photo interpretation was done by an experienced interpreter from the division of Forest Insect Research, Pacific Northwest Forest and Range Experiment Station. All 160 half-acre plots were studied, using a magnifying mirror stereoscope on a light table. For each plot an estimate was made of the volume of true firs in the dead and heavily-damaged classes, and the total volume of true firs in all classes. Initially an effort was made to separate the volumes in the lightly-damaged and undamaged classes, but a preliminary analysis indicated that this could not be done with sufficient accuracy to be useful.

The volumes were estimated by classifying each true fir as either large, medium or small, and applying an arbitrary volume per tree to each size. No effort was made to separate the various true fir species or to estimate quantities of other species.

Computations.

Area sampled by ownership. The area figures shown in Table No. 2 were determined by making a dot count on the map which showed the areas to be sampled by ownership. A grid of 5 dots per section, or one dot to 128 acres, was used. A total of 3,228 dots was counted within the boundary of the survey area.

Average per-acre volumes of true firs. The average per-acre volumes of true firs by damage class and ownership group were obtained by combining data from both the photo and field plots. The data obtained from the 49 field plots were used to adjust the estimates made on the 160 photo plots. The photo plots are a better sample of average damage conditions than the field plots because there are more of them, but they must be adjusted for photo-interpretation errors and the tree volume approximations used.

The method used to make these adjustments is a standard statistical procedure known as regression sampling or double sampling. Using the photo-estimated and field-tallied gross volumes for the 49 plots that were field checked, a linear regression line is computed. This shows the average relationship between the photo and field volumes. This relationship is then used to adjust the average volume obtained from all 160 photo plots.

Separate regressions were made for the volume of dead true fir, the heavily damaged class, and the total true fir volume in all classes. Coefficients of correlation between photo and field plot volumes were .75 for the dead class, .84 for the heavily damaged class, and .77 for the total true fir volumes in all damage classes. These coefficients are all highly significant and indicate that the photo interpretation of these damage classes is accurate enough to contribute a substantial amount to the survey accuracy.

Originally it was intended to use regressions for the lightly to moderately damaged class and the undamaged class. However, it turned out to be difficult to separate these two classes by photo interpretation so the regressions could not be used.

Each of the regressions for a given damage class was used to make four adjustments -- once to adjust the average of all 160 photo plots, and three other adjustments on the averages of plots falling in each of the three major ownership groups. Only minor corrections were necessary to make the sum of the three ownership classes equal the total.

As an example of one of these adjustments, the following figures are given for the total true fir volumes in all ownerships. The average gross volume in this class, based on the 49 field plots, was 37,680 board feet per acre. The average photo estimate on these same plots was 32,920 board feet per acre, about 13% low. The photo-estimated average for all 160 photo plots was 25,910 board feet per acre. This is about 21% lower than the photo estimate on the 49 plots.

The main reason for this is that a portion of the area set up to be sampled does not contain any true firs. The 160 photo plots are a representative sample of the whole area and some of them fall in the portions that do not have true firs. These were given zero volume and they lower the average for the 160 plots. In picking the 49 field plots, however, an effort was made to avoid putting any in areas not containing true fir. The average true fir volume on these plots is naturally higher.

The data from the field plots indicate that the photo estimates are low. When the average photo volume (25,910) is adjusted upwards by means of the regression, the final adjusted average is 29,672 board feet per acre, as shown in Table No. 3.

Since there were no regressions for the lightly to moderately damaged class or the undamaged class, the average per-acre volumes could not be obtained directly. It was necessary to obtain a figure for the sum of these two classes by subtracting the dead and heavily damaged classes from the total for all damage classes. This sum was then broken down into the lightly to moderately damaged class and the undamaged class in the same proportion that they occurred on the field plots.

Total gross volumes of true firs. Since the total area sampled (202,300 acres) was accurately known, and the adjusted average volumes from the combined photo and field data were representative samples of this area, the total volumes were obtained from the products of the two. Area figures were broken down into all six ownerships, but average per-acre volumes were obtained for only three ownership classes. It was necessary to group the four smaller ownerships, which constitute only 20% of the area sampled, into one class in order to get a reliable estimate of average volumes. To obtain estimates of the total true fir volumes in the various damage classes for these four smaller ownerships, the average per-acre volumes for the group were applied to the area in each ownership.

Approximate species breakdown of true fir volumes. The breakdown of the true fir volumes in the various ownership and damage classes into the different true fir species was based entirely on data from the 49 field plots. Consequently, some grouping of ownerships was necessary, and the resulting figures are only approximate. Ten of the field plots were taken in inaccessible areas (further than one mile from a road) and the remaining 39 field plots were taken in accessible areas. Since the species composition is likely to be different in these two area classes, it was necessary to keep the data separate. The field plots were sorted into four groups: (1) inaccessible, all owners; (2) accessible, Weyerhaeuser Timber Company; (3) accessible, Gifford Pinchot National Forest; (4) accessible, all other owners. Average species breakdowns for each damage class in each of these groups was computed and weighed by the appropriate area to obtain the breakdowns shown in Table No. 4.

Approximate species composition of stands sampled. This survey was not designed to provide a cruise of the standing green timber. However, standing green trees of all species were tallied on the field plots, and from these data it was possible to make some approximations of the average species composition for the stands that were sampled by the field plots. The methods used, and the limitations, are the same as for the breakdown of true fir volumes.

There is one very important difference between this breakdown for all species and the one for true fir volumes. The 49 field plots did not sample all of the 202,300 acres which were set up to be sampled. They sampled only that portion of this area which actually contained true firs. Therefore, the field plots constitute a representative sample of the true fir volumes, but they are not a representative sample of the average species composition on the 202,300 acres. They represent only that portion of this area which actually contains true firs. The average species composition on the entire area sampled can be expected to contain a smaller proportion of true firs and a higher proportion of other species.